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Defense acquisition has been plagued by inefficiency, cost overruns, and delays for centuries. Major Defense Acquisition Programs (MDAPs), evolutionary weapons programs with large investments in research and technology development, have been especially susceptible to these problems. A good deal of effort has been expended in reforming defense acquisition to make it more efficient. However weapons acquisition is still costly and inefficient. This study provides a background in the defense acquisition process and advocates for the adoption of private industry best practices, especially Knowledge Based Acquisition (KBA), in helping to increase cost effectiveness and efficiency.

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MASTER OF MILITARY STUDIES

A Best Practices Based Approach to Major Defense Acquisition Programs.

Lieutenant Commander
Jim Walls
April 12, 2010

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Executive Summary

Title: A best practices based approach to Major Defense Acquisition Programs.

Author: LCDR Jim Walls, United States Navy

Thesis: Despite reform measures the acquisition and development of new weapons systems has become increasingly costly and inefficient, plagued by cost overruns and delays. Best practices from private industry should be adopted in order to improve Major Defense Acquisition Program (MDAP) cost effectiveness and efficiency.

Discussion: Defense acquisition has been plagued by inefficiency, cost overruns, and delays for centuries. Major Defense Acquisition Programs (MDAPs), evolutionary weapons programs with large investments in research and technology development, have been especially susceptible to these problems. A good deal of effort has been expended in reforming defense acquisition to make it more efficient. However weapons acquisition is still costly and inefficient. This study provides a background in the defense acquisition process and advocates for the adoption of private industry best practices, especially Knowledge Based Acquisition (KBA), in helping to increase cost effectiveness and efficiency.

Conclusion: Private industry best practices, especially Knowledge Based Acquisition, have been proven to work in acquiring and developing new products and should be adopted across the defense acquisition enterprise.

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Illustrations

Table of Contents

Preface

This thesis is a result of my training, study of the acquisition system, and professional experience. As a Navy Supply Corps Officer I have a great deal of experience with acquisition on a small, shipboard scale and limited experience with Major Defense Acquisition Programs (MDAPs). One of the primary reasons I chose this topic was to educate myself on large weapons acquisition as I am at the point in my career where I will be dealing with these programs more often. MDAPs help shape our military and acquisition reform is a constant source of debate on the national level. As a Supply Corps Officer I feel compelled to learn more about these topics.

I want to thank my faculty advisors and classmates from Conference Group 3 for their encouragement. I also want to thank my mentor, Doctor Wineman, who provided excellent advice and showed great patience in helping me sharpen my focus and writing style. Finally and most importantly, I want to thank my wife, Theresa, for her patience, guidance, and assistance.

Inefficiency is a common thread in weapons system development and acquisition.[1] Frustrating delays and cost overruns are almost as old as American defense itself, as evidenced by the Navy's oldest warship, the USS CONSTITUTION, which had a cost overrun of 175 percent in 1797.[2] In order to make defense acquisition more efficient the Department of Defense (DoD) has adopted reforms and additional oversights such as the Nunn-McCurdy Act of 1982.[3] Unfortunately these reform measures have done little to make the acquisition and development of new weapons systems more timely, efficient, or economical. Additional reforms are still needed. However, in the meantime the DoD could improve cost and help to eliminate inefficiency by implementing Knowledge Based Acquisition (KBA), a proven method that improves defense acquisition efficiency and reduces costs.

Ancient History

Weapons acquisition is as old as warfare. For centuries, soldiers acquired weapons themselves or brought their own homemade weapons to the battlefield, while nations seeking a more expeditionary force acquired and relied upon primitive ships that transported their armed forces to new lands.[4] The mass manufacture of weapons may have started as early as the Ming Dynasty in 1405 with the creation of a large fleet of warships for global exploration.[5] In nineteenth century Europe, Napoleon helped further develop defense acquisition by moving the production of weapons from small, private artisans to large, industrial, state serving industries.[6]

World War I

In the United States weapons acquisition reached a turning point in World War I. The U.S. Military, specifically the Army, was materially unprepared for the war due to the service's unwillingness to adopt new weapons. As a result, the military had to build a vast acquisition organization to handle the demands of war in Europe. This effort failed to produce enough weapons and the Americans had to rely on equipment furnished by their European allies, primarily the French.[7] In response, the federal government established the War Industries Board in 1917 to encourage mass production of weapons and referee labor disputes in weapons firms[8]. World War I also saw the use of improved industrial techniques and the adoption of the automobile and airplane in combat.[9]

Mid 20th Century

Prior to World War II, and through the 1950s defense acquisition underwent a series of major changes. Lawmakers and government officials created regulations and exerted political pressure that moved defense acquisition out of the hands of the service chiefs and into the hands of civilian analysts at the Office of the Secretary of Defense (OSD). However, President Kennedy's Secretary of Defense, Robert McNamara, initiated the greatest change.[10] McNamara, former President of Ford Motor Company, introduced concepts such as systems analysis, life cycle costs, and total package procurement into the acquisition decision process. McNamara also introduced the Planning, Programming and Budget System (PPBS). PPBS advocated the idea that Planning (determining needs to fit strategic requirements), Programming (fitting those needs to particular programs), and Budgeting (funding programs) should all be part of one framework in fulfilling the nation's defense requirements.[11] PPBS was revolutionary in that it fit all elements of planning, programming and budgeting into one integrated framework and helped reduce the parochialism between the services. When McNamara took over as Secretary of Defense, each service had arbitrarily set budgets with no overarching cooperation or "vision" tying the services together in achieving the nation's defense objectives. One of McNamara's goals in introducing PPBS was to force the services into greater cooperation by requiring them to coordinate their respective budgeting issues as they worked through the PPBS cycle.[12]

National Strategy

Four documents are intended to guide major defense acquisition: the National Security Strategy, the National Defense Strategy of the United States, the National Military Strategy, and the Quadrennial Defense Review. The President traditionally issues the National Security Strategy the first year of each term. The National Security Strategy (NSS) identifies the United States' primary interests in issues such as sovereignty and access to international markets. The National Security Strategy often contains lofty language that identifies primary interests that are long standing foundations of the republic such as national sovereignty, access to international trade, and the protection of Americans home and abroad. Additionally, the National Security Strategy serves as an advertisement for the administration's goals. The National Defense Strategy (NDS) of the United States originates at the Office of the Secretary of Defense and presents the Secretary's basic principles of national defense while providing guidance on force structure. The Chairman of the Joint Chiefs of Staff (CJCS) writes the National Military Strategy (NMS). The NMS is designed to implement the National Defense Strategy. The Secretary of Defense, in consultation with the Joint Chiefs of Staff, issues the Quadrennial Defense Review (QDR) every four years. The Quadrennial Defense Review is sent to Congress the second year of every administration and defines force structures, modernization plans, and a budget plan that allows the military to successfully execute the full range of missions delineated by the National Security Strategy.[13]

Using the National Security Strategy, the National Defense Strategy of the United States, the National Military Strategy, and the Quadrennial Defense Review as guidelines, major weapons systems are developed by the Department of Defense through the interplay of three systems. These systems are the Joint Capabilities Integration and Development System (JCIDS);

the Planning, Programming, Budgeting and Execution system (PPBE); and the Defense Acquisition System (DAS).[14] JCIDS is a process that identifies a specific requirement for a capability, that capability is paid for through PPBE, and acquired through DAS. However, these three systems do not fall under the authority of one single overarching system. Rather, they operate in a "system of systems" manner that is referred to as the big "A" Acquisition process. By contrast, the process by which weapons systems are actually developed and purchased is often referred to as the little "a" acquisition process. Refer to Annex B for a graphic representation of the big "A" acquisition process and the way the systems interact.

A great deal of inefficiency and excessive cost are experienced during the little "a" acquisition process. Knowledge Based Acquisition is a disciplined approach to Major Defense Acquisition Program (MDAP) development and acquisition that can help reduce inefficiency and excess costs. Knowledge Based Acquisition is a management approach that requires adequate knowledge at critical junctures (knowledge points) during the little "a" acquisition process to make informed decisions.[15]

Joint Capabilities Integration and Development System

JCIDS is the process that the DoD uses to identify, assess, and prioritize what capabilities it needs to fulfill its missions. That is, JCIDS helps to generate the requirements that are satisfied during the PPBE and DAS processes. Often a requirement generated during JCIDS does not require the acquisition of an entirely new weapons system. These requirements may be satisfied through a change in doctrine, training, or organization. However, if a requirement needs a new weapons system it will be planned and paid for by the PPBE process and developed and purchased through the DAS process.[16]

Prior to 2003, DoD used a threat-based approach to identifying requirements. However, with JCIDS, the DoD moved to a capabilities-based approach in identifying military needs. In other words, instead of identifying requirements based on possible or perceived threats, the DoD shifted to a policy of identifying requirements necessary to meet the goals identified in the National Military Strategy, and the National Defense Strategy. The Capabilities Based Assessment (CBA) is the process within JCIDS that analyzes the military's needs and capability gaps and recommends both materiel and non-materiel solutions for bridging the capability gaps. If the CBA decides that a materiel solution (such as a weapons system) is needed, an Initial Capabilities Document (ICD) is prepared. The ICD justifies the need for a materiel solution to eliminate the capability gap. Once approved by the service oversight board the ICD is sent to the Joint Requirements Oversight Committee (JROC). The JROC, the committee responsible for identifying and prioritizing military requirements, must approve the ICD. To approve the ICD the JROC must validate the capabilities required to perform the mission, the gap in capabilities required to perform the mission, and the need to address the capability gap.[17]

Planning, Programming, Budgeting, and Execution

The Planning, Programming, Budgeting, and Execution (PPBE) cycle develops DoD's proposed budgets for all acquisitions, including new weapons systems.[18] As its name indicates, the PPBE is split amongst four phases: planning, programming, budgeting, and execution. The planning phase draws from the National Security Strategy, the National Military Strategy, guidance from the Combatant Commanders, and JCIDS.[19]

The programming phase takes guidance from the planning phase and attaches it to specific programs through the use of Program Objective Memorandums (POMs), six year spending plans that are reviewed every two years, issued by weapons acquisition programs. The programming phase utilizes POMs issued in the planning phase to develop and sustain programs. The programming phase also uses Program Change Proposals (PCPs) to change previous program baselines. The POM reviews take place at the Department of Defense with a final review at the Office of the Secretary of Defense (OSD) and the Joint Chiefs of Staff (JCS).[20]

The budgeting phase funds programs. The DoD allocates funds to programs on budget estimate submissions which are based on program expenditures the prior two years and future needs. Services and stakeholders in the Defense community heavily contest the budgeting phase since it speaks to the DoD's future priorities.[21] For example, the DoD makes a clear statement about the future of defense when it cuts off funding for an aircraft carrier while putting a great deal more money into Unmanned Aerial Vehicles (UAVs).[22]

The Execution phase begins when the President signs the defense appropriations bill. The DoD splits appropriations among seven categories: Research, Development, Testing and Evaluation (RDT&E); Procurement, Shipbuilding and conversion, Operations and Maintenance, Military Personnel, Military Construction and the Defense Working Capital Fund.[23]

The small "a" Defense Acquisition System

If a capability gap identified by JCIDS requires a materiel solution, and it is not available Commercial Off The Shelf (COTS), then the materiel solution is developed through the Defense Acquisition System. Once in the acquisition system a determination is made to place the acquisition into an Acquisition Category (ACAT). These ACATs are separated by the amount of funding they receive and their purpose.[24] ACAT 1, also known as Major Defense Acquisition Programs, must cost more than $365 million in Fiscal Year (FY) 2000 dollars for Research, Development, Test & Evaluation or have procurement costs of more than $2.19 billion in FY 2000 dollars.[25] Due to their high investment in RDT&E and reliance on new technology MDAPs are more susceptible to cost overruns and delays than less costly programs in lower acquisition categories.[26] The other acquisition categories, ACAT 1A, ACAT 2, and ACAT 3 are used for smaller programs and do not involve the same level of risk found in ACAT 1 MDAPs.

Milestone Decision Authority

In cases where a capability requirement necessitates the development of a new weapon system, the DAS uses a structure composed of five phases and three "milestones" to oversee and manage the acquisition program. Each phase has a specific purpose and each milestone has explicit requirements that a program must meet in order to move onto the next phase of the acquisition process. The Milestone Decision Authority (MDA) is responsible for deciding whether a program meets the milestone criteria and may move onto the next phase. Depending on the program, the MDA can be the office of the Undersecretary of Defense for Acquisition, Technology, & Logistics (USDAT&L), the head of the sponsoring DoD component, or the component acquisition authority.[27] Annex C contains a diagram of the milestone system of weapon system development and acquisition.

Materiel Development Decision

To get into the DAS, a program must pass a Materiel Development Decision (MDD) review where the MDA determines if a program will enter the acquisition management system and at what milestone. At the MDD review, the Joint Staff shows the JROC recommendations, and the sponsoring component presents the ICD, which details the need for a materiel solution. The materiel solution phase ends when the Analysis of Alternatives (AoA) is completed, the lead component recommends materiel solutions identified by the ICD and the program meets the criteria for the milestone where the program will enter the acquisition system.[28] The MDA can authorize a program to enter at any point in the acquisition system as long as the program meets the standards for that phase of the system. For example, a program can enter the system at Milestone B if it meets all of the Milestone B requirements.

Defense Acquisition System Phases

The first phase of the DAS is Materiel Solution Analysis. This phase determines potential materiel solutions for a required capability, and begins only after the JROC approves an ICD.[29] A program determines what technologies are necessary to develop a materiel solution and works to develop those technologies during the Technology Development Phase (TDP). Technology Development is the phase where Knowledge Based Acquisition can make the greatest impact.

To enter the Technology Development phase, a program must have an approved AoA, full funding for the technology development phase, and pass Milestone A. To pass Milestone A, the sponsoring service must submit a cost estimate for the system identified in the AoA, and the MDA must approve the system and the Technology Development Strategy. During this phase, technologies are developed and tested. The main requirements to complete the Technology Development Phase are the identification of an affordable program and the demonstration of the technology and manufacturing processes in a realistic environment.[30]

Knowledge Based Acquisition can also make a great impact in the Engineering and Manufacturing development phase. To enter this stage a program must have mature technology, approved requirements, full funding, and pass Milestone B. The program office develops the system, demonstrates full system integration, and makes preparations for manufacturing during the Engineering and Manufacturing Development. Preparations for manufacturing include determining manufacturing processes, designing the new system for ease of production, and managing cost.[31]

Engineering and Manufacturing Development consists of two subordinate stages: system integration and system demonstration. During system integration, the program office integrates the various subsystems into one system and produces a development model or prototype. During system demonstration, the model or prototype enters into testing to demonstrate its utility to the DoD and to ensure that the system can actually be manufactured.[32]

The final stage of the development process is Production and Deployment. Prior to entering this phase the program must pass Milestone C. At Milestone C, the MDA approves the beginning of Low-Rate Initial Production (LRIP). LRIP is a sort of "dry run" which prepares the manufacturing and quality control processes for a higher rate of production and provides a production created system for Operational Test and Evaluation (OT&E).[33]

Acquisition Reform

In order to control rampant inefficiency and skyrocketing costs the system for developing and obtaining Major Defense Acquisition Programs must be reformed. According to the House Armed Service Committee's report on the FY 2007 defense authorization bill, the DoD acquisition system is broken and beset by rising costs and lengthening schedules which results in more expensive platforms fielded in fewer numbers.[34] In response to these inefficiencies there have been efforts to reform the acquisition process.

The goal of acquisition reform is a weapons acquisition system that is more accountable and responsive. More often than not the problems with the acquisition system are inherent and structural in nature. These inherent flaws lead to the same problems repeatedly occurring. Two common causes are: contractors underestimating problems and costs for weapons development in order to win contracts and DoD customers changing requirements in the middle of weapons development due to changing battlefield conditions and political pressure, causing a ripple effect that leads to increased cost and delayed delivery times. Additionally, small defense sectors with a limited number of firms, and therefore limited competition, lead to higher prices.[35] However many of these flaws can be eliminated or mitigated through the disciplined application of Knowledge Based Acquisition.

The natural reaction to the skyrocketing costs and increased delays is to add oversight; however, this increased oversight has had a paradoxical effect. The cost of defense oversight doubled between 1980 and 1987, but did not lead to a better acquisition system. Instead, the increased legislation led to a more cumbersome and costly system. The Center for Strategic and International Studies (CSIS) noted that the legislative measures meant to reform acquisition have become larger and more complicated, leading to voluminous rules and regulations; imposing additional delays and costs on the process.[36] A system like Knowledge Based Acquisition that is based on the practical application of best practices and not on lengthy legislation, is the most practical way to eliminate or reduce problems in MDAPs.

Acquisition Workforce Development

One positive outgrowth of the concern over MDAP cost effectiveness and efficiency was the passage of the 1991 Defense Acquisition Workforce Improvement Act (DAWIA). DAWIA mandated the creation of a professional acquisition workforce and corps within each of the services and defense agencies.[37] Prior to DAWIA, an untrained workforce responsible for weapons acquisition existed in each of the services.[38] Although most of those working in weapons acquisition prior to DAWIA were hard working, conscientious professionals, there were few formal training standards. By adding proficiency standards DAWIA helped to professionalize the services' acquisition corps, made those working in acquisition more aware of acquisition's "rules of the road," and helped to cut down on corruption.[39]

Cost Controls

Cost overruns are a leading cause of acquisition reforms. While these reforms are well intentioned they often add one more layer of oversight to an already overburdened process, which in turn leads to longer review times, and increased cost. Instead of alleviating the problem of cost overruns acquisition reforms often make the problem worse. An adequate level of oversight is essential in MDAPs; the money invested makes requisite supervision a necessity. However excess oversight will just make cost overruns worse, not better.

The causes for the cost overruns themselves can often be traced back to poor original cost estimates, contractors deliberately underestimating costs to win contracts, unforeseen problems arising during development, and buyer –DoD- imposed changes mid-way through weapons development.[40] In 2007 development costs increased by an average of 40%, compared to an average increase of 6% in 2000.[41] These cost overruns led directly to reduced capability. As a result of cost overruns in MDAPs across the naval enterprise, the Navy may cut their proposed expansion from 313 ships to 279.[42] Growth rates for per unit costs of major systems like ships and aircraft are greater than rates for total defense procurement, total defense spending, and the Gross Domestic Product (GDP).[43] If per unit costs continue to climb unabated the DoD will find it increasingly difficult to fulfill all of its missions.

The reasons for cost overruns are related to poor cost estimates, wishful thinking on the part of private firms, and the government's changing requirements. Poor original cost estimates in MDAPs are a result of the evolutionary nature of many MDAP weapons systems. These systems are often completely new so cost data does not exist for comparison. Additionally private firms often intentionally underbid on contracts to get the DoD's business in the hopes of re-negotiating later when there are cost overruns. In new MDAP- level weapons systems immature technology which must be further developed leads to cost overruns. And perhaps most damning for the government, DoD imposed changes in the middle of a weapons developmental program have a ripple effect that can lead to costs that explode out of control.[44] This was the case with the first version of the F-22. The first two F-22 prototypes did not have a gun and instead relied on antiaircraft missiles. However after seeing the prototypes the Air Force insisted on a gun, resulting in substantial re-design and a considerable cost increase.[45]

The remedies for cost overruns are elusive. One of the reasons that curbing cost overruns is so difficult is that in focusing on increased costs DAS reformers treat the effects of an ill functioning system, and not the causes. In response to ever increasing costs in the early 1980s, Congress passed the Nunn-McCurdy Act in 1982.[46] The Nunn-McCurdy Act legislated that the DoD report programs with cost overruns exceeding 15% to Congress and that programs with cost overruns exceeding 25% be eliminated unless their national importance is personally vouched for by the Secretary of Defense. In response to the Nunn-McCurdy Acts directives many program offices simply restructured their programs once they started to approach the 15% and 25% tolerances.[47]

Delivery Delays

The causes of delivery delays in MDAP programs varies; however most can be traced back to the evolutionary nature of weapons programs and the high performance parameters and standards that new weapons programs must meet. Many MDAP programs are unprecedented and program offices are integrating technologies that have never been used together before. Additionally, the performance requirements that these weapons systems must meet are high and getting the weapons system to meet those standards often takes more time than initially anticipated.[48]

The program office may circumvent the approval process when approval authorities are convinced that the need for a quick delivery outweighs the need for the weapons system to meet all specifications. The DoD can make compromises where a weapon goes into service while continuing development. The United States initially adopted these practices during World War I and has used them since with mixed results. For example in World War II the P-51 Mustang proved to be very effective after circumventing performance standards.[49] However, not all concurrent development stories had a similar result. The Air Force rushed the F-100 Super Sabre through development for service in the Korean War. Unfortunately the F-100's rush through production and circumvention of performance standards resulted in a number of accidents that led to unnecessary deaths.[50]

Many observers blame the inefficiency of the weapons acquisition system on the lack of competition in developing MDAPs. Economists agree that greater competition between suppliers increases quality and choice, and lowers cost. Conversely, lack of competition and choice inhibits quality and leads to inefficiency. The lack of competition in supplying and developing new weapons systems directly relates to the high barriers to entry inherent in new weapons development.[51] For example, a firm needs an enormous amount of capital and a large infrastructure to develop and build something as large and complex as a new airplane or submarine. This lack of competition has recently received more attention. One of the areas of focus of the Weapons System Acquisition Reform Act of 2009 was increased competition within the acquisition system and a more detailed discussion of competition strategies for all MDAPs.[52]

In addition to the lack of suppliers in MDAP development, there is also a lack of customers. The United States is one of only a few nations that can afford to develop large weapons systems. Many firms are unwilling to dedicate a large portion of their business to one customer.[53]

Bureaucracy

Government bureaucracy is another reason for the lack of competition. Defense acquisitions, specifically MDAP acquisitions, are highly regulated and government contractors must contend with a cumbersome bureaucracy when developing new weapons systems. This bureaucracy is a substantial deterrent to firms in the private sector. Unlike in private industry, the DoD is more likely to require that private firms and contractors "open up their books" in order to see how the contractor is billing for time and accounting for cost. Most commercial firms are willing to provide goods to the DoD on normal business terms. However, the commercial firms are unwilling to change or reveal their internal operation to accommodate what may be a small one-time customer. Findings from an Air Force industrial base pilot program show that commercial firms have serious problems with government cost and pricing disclosure requirements. Commercial firms see these disclosure requirements as overly intrusive. Many disclosure requirements include requests for information on labor, material, and other information that may be proprietary data.[54]

The government has undertaken several initiatives to attract more firms to defense contracting. These initiatives include providing low-cost production facilities to contractors in order to lower the barriers to entry, using military test ranges to assist in product development, providing design information on similar systems, and forcing suppliers to share information with emerging firms who are interested in engaging in defense contracting.[55]

Overly Stringent Requirements

Critics of the Defense Acquisition System identify overly stringent requirements as a cause of cost overruns. Items in the military must meet a high set of standards commonly referred to as military specifications, or MILSPECs. An aircraft engine that is perfectly suitable for commercial travel may not stand up to the rigors imposed by the corrosive effects of salt air on an aircraft carrier's flight deck or the blowing sand on a runway in Afghanistan. While MILSPECs ensure that the warfighter gets suitable equipment, they often exclude commercial items that would provide competition and drive down costs.[56] Dual use items (both military and commercial) are usually more affordable. Additionally dual use firms that provide products to both the military and civilian industry can provide the DoD with access to the advanced technologies and capabilities of the commercial sector.[57] In 1994, Defense Secretary William Perry mandated that the military move towards the use of COTS products for non-critical items. However, MILSPEC requirements remain for items that must perform in both arctic and desert climates, work to save lives in combat or emergency medical situations, survive massive gravitational forces in air and space, or explode with certainty when directed at an enemy target. Many MDAPs meet these requirements, so MILSPECs are still a big part of the cost for MDAPs. Furthermore, commercial items often lack the data and use history to determine if they will be suitable for military applications.[58]

The natural response to increasing cost and delivery delays for MDAPs is additional oversight. Much of this oversight began during Robert McNamara's tenure as Secretary of Defense during the Kennedy and Johnson administrations. McNamara did not trust the services to cooperate with each other and subvert their own interests for those of the DoD so he took steps to civilianize and systemize the acquisition process while instituting the process that is now

PPBE.[59] However, despite best intentions additional oversight usually has a paradoxical affect on defense acquisition. The additional restrictions and reviews that programs must undergo with increased oversight often result in increased costs and weapons programs that cannot meet deadlines.

<u>Knowledge Based Acquisition</u>

Knowledge Based Acquisition is a management approach which requires adequate knowledge at critical junctures (knowledge points) throughout the acquisition process to make informed decisions.[60] The best approach for improving acquisition efficiency and cost effectiveness is adopting practices from private industry, such as Knowledge Based Acquisition, that focus on the technology development and engineering and manufacturing development phases of the acquisition process. In many of their reports on defense acquisition the Government Accountability Office (GAO) advocates private industry best practices, specifically KBA, and uses KBA in assessing the health of MDAPs. According to the GAO, the KBA approach to developing products encourages realism, honesty, and reasonable expectations. Ensuring technology is mature and functional is the foundation of this approach.[61]

There are three key points, or milestones, in KBA that all take place during the technology development and engineering and manufacturing development phases. The weapon program should not move forward until the following knowledge points are satisfied: [62]

- The program office makes a match between customer's needs and the available technology
- The product's design meets performance requirements
- A manufacturer can produce the product within cost, schedule, and quality targets.

The first knowledge point can be thought of as a milestone that takes place at the end of the technology development phase and is satisfied when the program office makes a match between the customer's needs and the available technology. This means that the program does not move forward into the engineering and manufacturing development phase unless a successful match is made between existing technology and the customer's needs. Satisfying this knowledge point frees the program manager from developing immature technology when he should be concentrating on the design and production of the final product. This is a key part of the development process since failing to resolve technology problems during the technology development phase can result in a tenfold cost increase if the program office fixes the problem during product development and an even more significant cost increase if the program office fixes the problem during production.[63]

In their July 1999 report "Better Management of Technology Development Can Improve Weapon System Outcomes" the GAO provided a template to measure technology readiness, presented examples of MDAPs that used appropriately mature technologies, and furnished evidence that programs that employed mature technologies were more apt to meet time and budget goals than programs that used immature technologies.

The GAO measured the technological maturity of 23 programs using Technology Readiness Levels (TRLs) in their July 1999 report. TRLs are analytical tools that determine the readiness of technologies to be incorporated into a system. The TRLs range from 1 (basic principles observed and reported) to 9 (Actual system validated through successful mission operations). See Annex 3 for a more complete description of TRLs. The GAO found that programs which scored high on the TRL chart prior to entering the Engineering and

Manufacturing Development phase were the most successful in terms of meeting budget and deadline commitments.[64]

The periscope on the Virginia class submarine and the Army's brilliant anti-armor submunition program offer examples of the value of mature technology. The Defense Advanced Research Projects Agency (DARPA) matured a revolutionary periscope technology to a TRL of 9 before it was included on the Virginia class attack submarine. As a result of its high TRL the periscope was delivered on time and on budget. Conversely the key technologies for the Army's brilliant anti-armor submunition were at TRLs of 2 and 3 when weapon system development began, resulting in an 88-percent cost growth and a 62-percent slip in schedule.[65]

Applying KBA to the DAS may be difficult due to the inherent nature of weapon system development in the DoD. KBA demands that technology be mature before the technology is included in a weapons development program; if the technology is not mature then KBA dictates that the technology should not be included in a weapon system or that an acquisition program should not be launched for that weapon system. Unlike private industry, the DoD environment encourages initiating product developments that entail more technical uncertainties and less knowledge about a new weapon system's performance and production risks. One of the difficulties in instilling KBA is that novelty is encouraged in DoD weapons systems. The new features and radically different weapons systems promoted by DoD program managers rely on immature technologies. As a result these managers rely on maturing technology during product development when the emphasis should be on product design and manufacturing.[66]

Finally, in the GAO's view many program offices, contractors, and acquisition officials take a "head in the sand" approach to technology development. This aversion to disappointing news and unfavorable results is why many are reluctant to adopt KBA. That is, not having basic knowledge about the maturity, applicability, and ability to produce a weapon system can be perceived as better than knowing that problems exist since big problems could lead to a program either never being launched or being cancelled.[67] By contrast, most commercial firms fully develop technology before entering the design and production phase and do not ask their product managers to develop technology.[68]

Mandating the adoption of only mature technologies in MDAPs is very difficult, however, not impossible. Program managers and sponsors must be given the latitude to wait for technology to mature, or when feasible to change weapon system parameters so that mature technologies may be incorporated. In the private sector Hughes communications delayed the development of one of their commercial satellites until critical solar cell technology had matured, this took over 10 years. Rather than proceed with immature technology Hughes waited for the proper technology to mature rather than suffer through missed deadlines and cost increases. In MDAP development Navy program managers integrated an existing weapon ejection system on the Virginia class attack submarine when technology did not sufficiently mature on the weapons ejection system they wanted to use.[69]

The DoD should re-prioritize its emphasis on research and technology in order to advance technologies to greater maturity prior to adoption into MDAPs. Presently it is easier for weapons programs to get funding than it is for Science and Technology programs that are not tied to a specific weapons program. The DoD usually does not fund science and technology organizations to take technology past TRL 5, (basic feasibility). In order to get a technology past stage 5 it must be moved to a weapons system that has greater funding and support. However as has been seen from the Virginia class submarine's DARPA-developed periscope mature technology is much more likely to result in favorable outcomes.[70]

After the DoD has determined that a technology meets the necessary maturity level and an initial prototype has met the appropriate standard, the next step is the engineering and manufacturing development phase.[71] During this stage the program manager must successfully integrate all technologies into a useful weapons system and design a system that can be manufactured. During engineering and manufacturing development the last two knowledge points must be satisfied; the product's design must meet performance requirements; and the manufacturer must be able to produce the product within cost, schedule, and quality targets.[72]

The engineering and manufacturing development phase has two separate parts, system integration and system demonstration. During systems integration the program office is responsible for integrating (not developing) already mature technology into a functional weapons system. Systems demonstration is the point in the program where the program office must design the final prototypes and develop manufacturing processes that can reliably produce the weapon system.[73]

If all of the technology used in the weapons system is fully mature prior to the engineering and manufacturing development phase, systems integration (the first part of the engineering and manufacturing development phase) will be the program manager's first foray into really taking over the program. System integration is the first time the program manager will have a clear picture of the task in front of him: as such the DoD should give the program manager some flexibility in developing schedules, budgets, and performance targets during system integration.[74]

Systems integration should end with a critical design review of engineering drawings and confirmation that the system's design will meet requirements. This is the second key knowledge point or requirement associated with KBA. The system integration should also end with more firm cost and schedule targets and a final set of requirements for the initial version of the weapon system.[75]

DoD programs that were able to satisfy the requirements for the second knowledge point in KBA were much more likely to meet schedule and budget goals. The AIM-9X Sidewinder missile and the F/A-18E/F Super Hornet aircraft captured design and manufacturing knowledge by knowledge point two and limited cost increases to four percent or less and schedule growth to three months or less. The AIM-9X had over 90 percent of its drawing completed at its critical design review. The F/A-18E/F had 56 percent of its drawings completed at its critical design review. Conversely the F-22 Raptor aircraft, and the Patriot Advanced Capability-3 (PAC-3) missile did not have sufficient design and manufacturing information at knowledge point two, resulting in significant cost growth and delivery delays.[76]

The final step of the engineering and manufacturing development phase prior to production and deployment is systems demonstration. During system demonstration, the program manager has enough data to legitimately commit to firm cost, schedule, and performance targets.[77] If the product design and key manufacturing practices are fully demonstrated in system integration and system demonstration, the third key requirement associated with KBA can be met. With a mature product design and determination of the key manufacturing processes low rate production's sole focus can be building operational test articles and maturing the production process. Low rate production can safely conclude when a product has met user requirements in operational conditions and manufacturing processes are under statistical process control, or using statistical methods to monitor and control manufacturing so that it produces products with no variation. [78]

Programs that were able to satisfy knowledge point three were better able to meet their cost and schedule restraints than those programs that were unable to meet knowledge point three. The F/A-18E/F program took steps early in product development to identify crucial manufacturing processes and gather process control information. Because of the program office's early emphasis on manufacturing F-18 E/F unit costs have not grown since its critical design review and its schedule has been delayed by only three months. Like the F-18 E/F the AIM-9X program took steps early in the product's design to make it easier to manufacture. In addition to having a stable design at the critical design review the AIM-9X program office took valuable inputs from a team member with a manufacturing background and identified critical manufacturing processes early in the AIM-9X's development.[79]

Programs that do not have solid manufacturing plans had more difficulty meeting cost and schedule requirements. The F-22 experienced several problems during its initial production run due to its inability to identify its key manufacturing processes and get them in statistical process control. These problems included design changes, labor inefficiencies, cost increases, and schedule delays. The PAC-3 missile also experiences significant delay and cost overruns due to its inability to satisfy knowledge point three. The PAC-3 had insufficient knowledge of key manufacturing processes, resulting in subsystems that did not fit together properly and many failed performance tests. Additionally the PAC-3 had $100 million in additional costs related to manufacturing problems.[80]

Conclusion

Despite reformers' best intentions, many of the measures aimed at increasing MDAP efficiency have been either ineffective or made the process more inefficient and costly due to new requirements brought on by additional oversight. Instead of additional reforms aimed at the

DAS the DoD must take a more holistic approach to acquisition reform. Areas that need to be addressed are lack of technical maturity, lack of sufficient knowledge prior to weapon system production, inadequate competition in MDAPs, private firms that underbid to win contracts only to experience cost overruns later, the role that MILSPECs play in driving up costs, and private firms who will not work with the government due to overly obtrusive pricing inquiries.

The problems facing the DAS are numerous. However some of the most vexing problems can be mitigated through adopting KBA. KBA is a management approach which requires adequate knowledge at critical junctures (knowledge points) throughout the acquisition process to make informed decisions. [81] KBA's primary focus is process discipline.[82] KBA requires that the DoD have the discipline to not adopt immature technologies into MDAPs, or to simply not initiate MDAPs that are dependent on maturing technology. Attempting to mature a technology while simultaneously adapting it for use in an MDAP puts too much pressure on the responsible program manager and almost inevitably leads to increased cost and missed deadlines. Unfortunately, the willingness to adopt immature technologies is aided by the DoD's affinity for novelty in their weapon systems.[83]

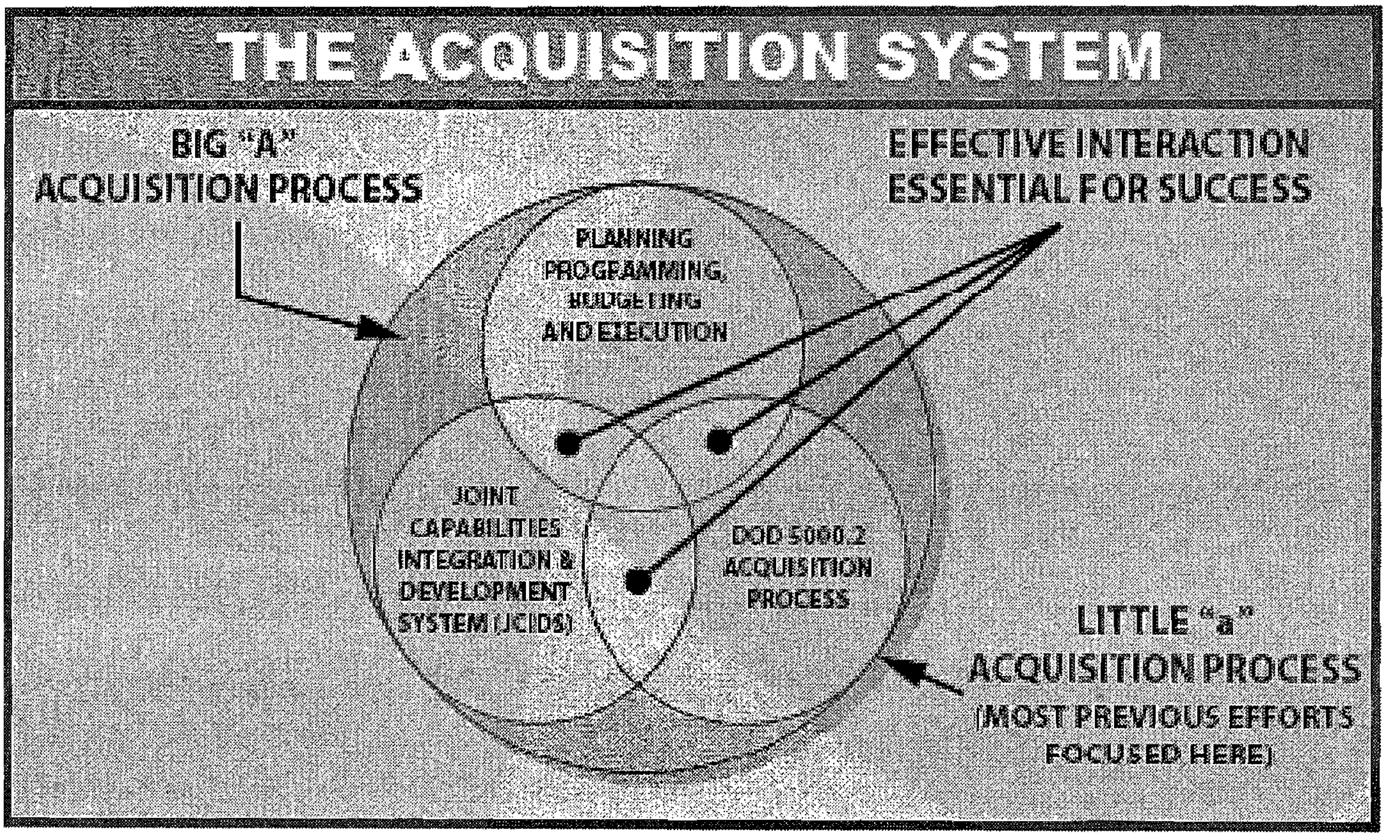
This paper has provided an outline of the Defense Acquisition System, its problems, and a methodology, KBA, which can be used to help alleviate some of the inefficiencies that MDAPs experience. Defense acquisition is a vast subject that requires further study however as can be seen with programs like the Virginia class submarine periscope and the F/A- 18 E/F Knowledge Based Acquisition is a process that has proven to increase MDAP efficiency and cost effectiveness.

Annex A
Acronyms

ACAT - Acquisition Category
AoA - Analysis of Alternatives
CBA - Capabilities Based Assessment
COTS- Commercial Off The Shelf
CJCS- Chairman of the Joint Chiefs of Staff
DAS - Defense Acquisition System
DAWIA - Defense Acquisition Workforce Improvement Act
DoD- Department of Defense
GAO - Government Accountability Office
ICD -Initial Capabilities Document
JCIDS - Joint Capabilities Integration and Development System
JCS - Joint Chiefs of Staff
JROC - Joint Requirements Oversight Committee
KBA - Knowledge Based Acquisition
LRIP - Low-Rate Initial Production
MDA - Milestone Decision Authority
MDAP - Major Defense Acquisition Programs
MDD - Materiel Development Decision
MILSPECs - Military Specifications
NDS- National Defense Strategy of the United States
NMS - National Military Strategy
NSS- National Security Strategy
OSD - Office of the Secretary of Defense
OT&E - Operational Test and Evaluation
PCP -Program Change Proposals
POM - Program Objective Memorandums
PPBE - Planning, Programming, Budgeting and Execution
PPBS- Planning, Programming and Budget System
QDR- Quadrennial Defense Review
RDT&E - Research, Development, Testing and Evaluation
TRL- Technology Readiness Level
UAV - Unmanned Aerial Vehicle
USDAT&L - Undersecretary of Defense (Acquisition, Technology, & Logistics)

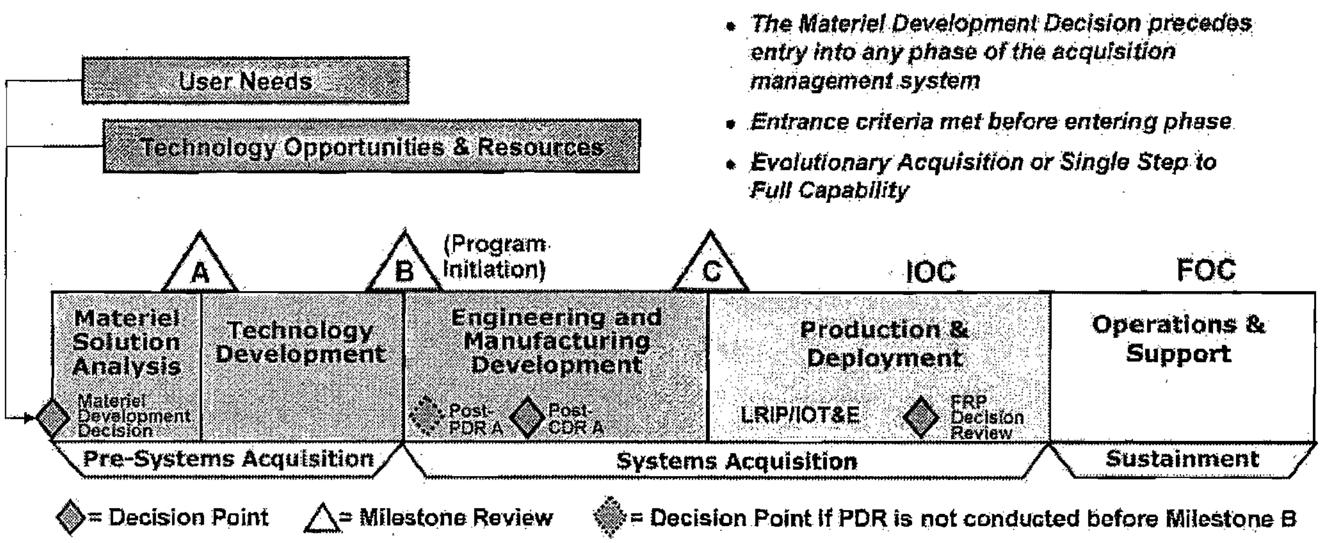
Annex B

The Capital "a" Acquisition System[84]



Annex C

The small "a" Defense Acquisition System[85]



Annex D

Technology readiness level Descriptions[86]

TRL 1. Basic principles observed and reported. Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.

TRL 2. Technology concept and/or application formulated. Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.

TRL 3. Analytical and experimental critical function and/or characteristic proof of concept. Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.

TRL 4. Component and/or breadboard validation in laboratory environment. Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.

TRL 5. Component and/or breadboard validation in relevant environment. Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.

TRL 6. System/subsystem model or prototype demonstration in a relevant environment. Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.

TRL 7. System prototype demonstration in an operational environment. Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.

TRL 8. Actual system completed and "flight qualified" through test and demonstration. Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.

TRL 9. Actual system "flight proven" through successful mission operations. Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions

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